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Research

Mathematics for/from Society: The Role of the Module in Modernizing Japanese Architectural Production

Abstract. This paper presents an examination of the process of the development of module in the works and theories of Japanese architect Ikebe Kiyoshi (1920-79). Ikebe based his idea of module on the belief that “Beauty is Mathematics.” He applied his ideas of module in various ways from the 1940s to the 1970s. Analyzing his ideas and works against their historical background, the social and creative meanings of the idea of module and of mathematics in architecture will be re-examined. This allows us to see how Ikebe developed his ideas of module from a characteristic mathematical approach, and how he developed his idea of mathematical logic into his creative theories based on the flexible nature of people’s lifestyles and social conditions. Going beyond the cultural and social differences and the limitations of Le Corbusier’s Modulor, the idea of module as the method for organizing human space in a harmonious manner was reframed in Ikebe’s works, and was developed in a more flexible mathematical way.

Introduction

In 1946 Le Corbusier created a drawing of his idea of Modulor with the aim of enabling effective industrial mass production of architecture by unifying three factors in the architectural module: human scale; the visual harmony of the Golden section; and the imperial/metric measurements based on the Fibonacci series. Nevertheless, in a 1997 survey of Japanese architects by the periodical *Kenchiku Gijutu*, most responded negatively to the idea of the module, and many recognized it as a fixed numerical system based on abstract mathematics. (To be more precise, the responses were “it disturbs the freedom of design by equalization of measurement”; “it equalizes the quality of space”, and “it disturbs the variety of designs”.) On the other hand, the idea of standardization of measurements has been consistently important in the creation of architecture and public spaces, and particularly in mass social housing in global society.¹ However, architects hardly make any significant contributions towards resolving these difficult issues because their profession has become oriented toward formal design. The narrowness of architects’ understanding of the idea of module and their inability to contribute to the discourse on social housing are concomitant, and signify the divisions within architectural design, production systems, the reality of human life, and the representation of social ethos. By referring to the Greek notion of modulus, Heidegger [1971] explained that selection of measurement is a human attempt to create a society based on benevolence. In that sense, the idea of module implies the symbolic role of mathematics in creating social ethos in architecture. In order to resituate the architectural profession within the social context, it is important to re-examine the idea of module in a wider perspective.

In this paper, I will examine the process of the development of module in the works and theories of Japanese architect Ikebe Kiyoshi (1920-79), who examined the idea of module based on his belief that “Beauty is Mathematics.” Ikebe applied his ideas of module in various ways from the 1940s to the 1970s. Through an analysis of his ideas and works against their historical background, the social and creative meanings of the idea of module and of mathematics in architecture will be re-examined. This study clarifies how Ikebe developed his ideas of module from a characteristic mathematical approach, and how he developed his idea of mathematical logic into his creative theories based on the flexible nature of people’s lifestyles and social conditions. Going beyond the cultural and social differences and the limitations of Le Corbusier’s Modulor, the idea of module as the method to organize human space in a harmonious manner was reframed in Ikebe’s works, and was developed in a more flexible mathematical way, influencing future architecture.

The Modulor of Le Corbusier

For the purpose of this study, I would like to briefly summarize Le Corbusier’s explanation about the factors and the process of organizing his idea of Modulor as described in his book *Le Modulor* [1954]. Le Corbusier started working on the validity of the Golden section in designing architecture and discussed the ideas of standardization for an architectural unit and its system of mass production in *L’Esprit Nouveau* from the beginning of the 1920s. With a group ASCORAL (Assemblée de Constructeurs pour une Renovation Architecturale) in 1942, which opposed the average value measurement system between imperial and metric of the Association Française de Normalisation (AFNOR), he began working on the unification of the proportion grid, the Golden section and human scale. After World War II, they put absolute size into the geometrical analysis of the proportion grid, and discovered that the Fibonacci series could organize the measurements derived in his system. Subsequently Le Corbusier started to advocate his idea of Modulor worldwide as a set of measurements to unify the imperial and metric measurements for the industrialization of architectural production, thus applying it in his projects, such as the Unite d’habitation in Marseille from 1945 to 1947.

Here, I would like to point out two issues. First, in the concept of Modulor, Le Corbusier’s idea of mathematics was mainly geometrical. The Fibonacci series was appropriated into his system after his application of absolute size into the system. Second, his idea of Modulor primarily aimed at realizing the unification of imperial and metric measurements, not by a convenient averaging method, but by his universal ideology for architecture.

The background of the creation of a national module in Japan

Shaku, a 30.303-cm. module system,² was originally introduced into Japan from China, and was developed in the apprenticeship system based on the dominant role of carpenters and on their canonical rules. The *shaku* module was further elaborated in the Edo period by master carpenters for the organization of a coherent structural system called *Kiwari* (sizing of timbers).³ Later, the columniation systems of *Kiwari* were developed further in *Hashirawari* (arrangement of columns).⁴ Particularly in the *Sukiya* style, the placement of the Tatami mat in the whole area of the room became common, and the sizes and arrangement of the Tatami mat became systematized in *Tatamiwari*. In this process, the size of the Tatami mat became unified and linked to the measurement of the Japanese body. Thus, the structural and material balances of Japanese architecture were closely

united with its spatial proportions, functions, ornamentations, detailed arrangement of facilities, and human scale.

However, the *shaku* module differed according to geographical area. Examples are *Kyoma* in the western part of Japan, which is based on the distance between the surfaces of column and has a 6.3 *shaku* module, and *Inakama* in the east, which is based on the distance between the centers of columns, and has a 6 *shaku* module. The sizes of the Tatami mats differ accordingly. The cutting of timbers and the application of *Kiwari*, *Hashirawari* and *Tatamiwari* were all controlled by the carpenters, whose knowledge tended to be based on their local and conventional resources and networks, which were different from mechanical standardization.

Discussions to establish a national module

After the Meiji reformation, the Japanese government built many institutional buildings in Western styles, and the metric system became symbolic not only of creating fire resistant cities but also of rationalizing and modernizing architectures, and of people's lifestyle. In order to industrialize the nation, the government continuously tried to replace the *shaku* module with the metric system and to modernize the traditional carpentry system. In 1919, the government tried to establish a national module of weights and measures, and a standardization of industrial production based on the metric system. The Japanese Architectural Academy also tried to change the *Kyoma* to a 2-meter module. But, during World War II, the Wartime Architectural Standard based on the *shaku* module was revived to protect the cultural identity of Japanese architecture. After the war, the Kenchiku-Kijunho (Architectural Standard Law) and the Kyotu-Jutaku-Kensetu-Shiyosho (Common Specifications for Housing Construction) were established by the government to legitimate the meter module in 1950. Thus, influenced by social and political conditions, the traditional *shaku* and the meter modules were each approved in turn.

Inspired by the translation into Japanese of Le Corbusier's *Le Modulor* in 1953 [Yoshizaka 1976], another academic committee for the creation of a national module was started in 1954. Their discussions focused on the following three points; whether to select the *shaku* module or the metric module; methods for industrialization and standardization of architecture; and the selection of the modular coordination. However, opinions about whether to select the *shaku* or the metric modules were highly diversified according to the members' occupations and interests. In the summary of these discussions, they agreed on a definition of the idea of a module,⁵ but could not reach any recommendation for unifying the two modular systems. In 1955, the Jutaku Kodan (Institution of Public Housing) was established to supply public housing for the suddenly increased demand for housing all over Japan. Despite such conclusions by the committee, the Japanese government legitimized the JIS meter module, and prohibited the usage of *shaku* module in 1958. Nevertheless, people continued to favor the Tatami mat houses, and carpenters continued using the *shaku* module. Ironically, the industrialization and the standardization of houses in Japan from the 1960s progressed concomitant with usage of the *shaku* and the metric modules according to each element, and the government abrogated the prohibition of the *shaku* module.

Development of the ideas of minimum houses

In spite of the confusion in the creation of a national module, the ideas for the minimum house developed consistently in Japan after the Kanto earthquake in 1923. The

members of a public institution Dojunkai, the Ministry of Interior, architects and scholars researched people's living and working conditions, and based on this experience and on the information from European housing policies and examples, they built public housing in concrete, and detached houses with traditional timber structures. In particular, information about the idea of standardized prefabricated collective housing in Germany, such as those of Walter Gropius in 1910, was introduced into Japan at that period.

During World War II, a number of prefabricated houses were designed. A Japanese architect named Ichiura Ken introduced the designs by Albert F. Bemis, and built 200 wooden prefabricated houses based on the Imperial module similar to those of W. Gropius's Trocken Montage Bau. In 1946, the Kogyoka-Jutaku-Seisan-Kyokai (Institution of Industrialized Housing Productions) was established to apply military technology to the housing industry, and a Japanese architect named Maekawa Kunio, a Japanese pupil of Le Corbusier, designed the first factory-made house "Premos 7" using 1-meter wooden panels. As a result, by accepting the differences between the Imperial, metric and *shaku* modules mainly in their numerical senses, and without resolving their cultural contradictions, Japanese architects and contractors kept constructing prefabricated mass housing.

Jean Prouvé's prefabricated minimum house

A Japanese architect named Ikebe Kiyoshi was one of the main members of the academy's national module committee, and continued the study of the module throughout his life. One of the reasons for his strong interest in the module was his involvement in the wartime project of prefabricated package housing from 1942 to 1945 at the Kokudo Kensetu Senso Kumitate Kennchiku Kenkyujo (Institution for the Construction of the National Wartime Prefabricated Architecture) by Sakakura Junzo. Sakakura had worked in Le Corbusier's atelier, and tried to translate French engineer Jean Prouvé's SCAL (Société Centrale des Alliages Legers at Issoire) (fig. 1), made with lightweight steel frames and wooden panels, into Japanese traditional wooden structures.⁶ In 1938 Prouvé started to design prefabricated house for military barracks based on the portal frame system. In 1939 he collaborated with Charlotte Perriand and Pierre Jeanneret to design the first building with central metal portal frames and wooden panels, which was designed to be transported by truck and to be assembled with only two workers. The wooden panel was based on 3.3 ft. modules and interchangeable elements, and could be produced in different variations and sizes according to the designated function [Peters 2006: 36].

According to Nils Peters, even though his constructions are far advanced technologically for his period, his design procedure was a "tactile working method" [2006: 11]. He was not interested merely in the technological aspects of the prefabrication, but more in exploring the expressive and economic possibilities and social significance of materials, which was only attained from his direct experience as a craftsman, and his dream for industrialization [Peters 2006: 17; Sulzer 1999: 11]. In contrast to Le Corbusier, Prouvé, as a furniture designer, was not explicitly interested in the ideology of human scale, and recognized that the beauty of the form derives from the expression of its process of construction. In his designs, the functions of architectural space and forms were defined by reflective communications between architects, builders and users.

Fig. 1. Jean Prouvé's SCAL project [Sulzer 1999: 265].
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Fig. 2. Sakakura Junzo's applications of Prouvé's idea to a Japanese house, 1941
[Matsumura 1999]

Ikebe studied Prouvé's model in detail, struggled with problems of its translation into a Japanese timber structure, and was apparently deeply influenced by Prouvé's ideas and methods (fig. 2).

Ikebe's "Beauty is Mathematics"

In *Dezain no kagi* (Keys for design), Ikebe explained his initial inquiry about the ideas of module and prefabrication, and his approach to these themes:

While I worked on the prefabrication of houses during the war, I encountered the most serious problem in the difficulty of understanding the inevitable human quality of space. Thus, after the war I decided to deny the hasty approach for industrialization of prefabricated buildings, and to work on how big a space a person actually needs in his life. ... This is a historical and universal theme, such as examined by a twelfth-century Japanese poet and by Le Corbusier. ... However, my approach was different from Le Corbusier. After pursuing the designs for these themes, I tried to return to the human standpoint to conceive these problems. In other words, I tried to examine how people can find the quality of space with architecture. Thus, I started to work on the idea of minimum volume with three dimensions instead of two, which the European modernist used [Ikebe 1979: 18].

He stated that architectural design has to begin by examining how small we can make the unit space for people, and is not about the appearance of form but about the realization of the desirable relationship between people and objects [Ikebe 1979: 22, 122]. Ikebe was opposed to his fellow Japanese architects' enthusiasm in following the ideas of Le Corbusier and other modernist architects, and instead, wanted to return to the real and qualitative nature of the relationship between man and his space.

He argued that "Beauty is Mathematics," because both exist with actual purposes and in people's cognitive and productive processes [Ikebe 1979: 94]. The beauty exists in the process of creating things, and mathematics is always implied in our act of finding solutions for problems. In his conceptualization of the module, he continuously explained that it is not merely the measurement but that it is derived from the proportion of the living space. He assimilated the unit of the module with the number 1 in mathematics as the primal element, and argued that both should be different in each culture. In his opinions for the ideas of module and designs of prefabricated housings, it is clear that Ikebe shared Jean Prouvé's substantial, humanistic, and process-orientated approaches.

Ikebe's critical standpoint was inevitably affected by his social situation in Japanese modernization after the war. In his article "Kenchiku no kindaishugiteki keiko" (Modernist characteristics in recent Japanese architecture) [1958] Japanese historian Inagaki Eizo wrote that Japanese architects had not critically examined their works during World War II, and retained their abstract idealism without addressing the reality of people's daily life. Ikebe continued to re-examine the problems in his wartime work and presented his study of the module as the new direction of architecture for post-war Japan. He also criticized Japanese architects' superficial preference for the aesthetics of traditional architecture. In the committee, he kept insisting on returning to the origin of the idea of module in rejection of the convenient compromise of the metric module, and on objectifying the traditional *shaku* module as one of the advanced aspects of Japanese architectural culture based on the material, form, technologies and people's lifestyle in the past.⁷

Ikebe believed that architectural standardization should not be aimed at merely for the sake of its industrialization, but should be accomplished by placing an emphasis on the complexity of human nature. In 1955 Ikebe described his intention in the study of the module as the foundation of freedom in designing, and as the key to reframing the idea of architectural design and production.

Numbered houses

Through approximately 100 house designs, Ikebe continually redefined his module systems. In the design of house No. 1 (fig. 3), he used a 3-m. module derived from J. Prouvé's work, and he tried to liberalize the design of the minimal house by carefully reevaluating people's activities in each space. In the design of house No. 3 (fig. 4), he used a 75-cm. module, which is a quarter of 3 m, and tried to apply this module in three-dimensional space by using it in the designs of desks, windows, stairs, passages and the restroom.

At this stage he compared his 56.25-cm. module, which is one element of a 75-cm. module (75 x 0.5 x 1.5), with the German Octameter module, and the *Kujira* (Whale) module for sewing Kimonos in Japan. He stated that they are all very close to each other in both the number itself and the coordination systems, which proves the universal validity of this module.

In the design of house No. 38 (fig. 5), which was commissioned by a Japanese publisher to introduce the ideas of the Case Study House in the American periodical *Art and Architecture*, he used an 8-cm. module based on his idea of the GM module (General Module: $X=2^n+2^{n-1}p_1+2^{n-2}p_2+2^{n-3}p_3$, ($p_1, p_2, p_3=0$ or 1)), which he derived from the measurement of peoples' living space. In this project Ikebe tried to prove that this module could be widely applied to the measurements of human movement, furniture, all parts and form of the house, and to its site plan on an urban scale. He explained that the new module would be effective in five ways: the joining of space, the change of spatial quality, the development of organic space, the separation and contrast of spatial structure, and the change of the constructional system of space [Ikebe 1995].

Fig. 3. Ikebe Kiyoshi's house No. 1 [Ikebe 1995]

Fig. 4. Ikebe Kiyoshi's house No. 3 [Ikebe 1995]

Fig. 5. Ikebe Kiyoshi's house No. 38 [Ikebe 1995]

This idea of the adaptability of the module system to the change of architecture in time shows his characteristic ideas of architectural function. He suggested that in modernity, according to the acceleration of the organization of human life, the idea of the function of space became too static. In other words, he conceived of architectural function as being formulated in response to the changes in people's lives.

Fig. 6. House No. 71. First stage first- and second-floor plans (Owner's private collection)

House No. 71 (1962-1975) is one of the examples of his flexible house designs, which developed according to the change in people's lifestyle.⁸ He designed this minimal house for a young family with two children. The unit module is 96 cm. and the original plan is a 6 x 4 rectangle in two stories (fig. 6). It is constructed with timber beam and frame structure with wooden panels. Even though it was a regular timber structure, the materials were all produced in factories, such as laminated wood beams and flexible boards, and the design was economically rational with bare structural beauty. The height of the interior space and all elements were designed with the module. On the other hand, he used highly industrialized kitchen facilities and bathroom equipment, which are disproportionately expensive compared to the other structural materials.

After an expansion of a back room in the second stage, and after the children grew up, in the third stage, Ikebe divided the second floor main room into two to provide individual rooms for the children with a top light, moved the stairs and kitchen to the back room, moved the bathroom to the second floor, and added the second floor on the back (figs. 7-9). The validity of the module was continually re-examined in these transformations, and he applied different design methods and elements to resolve the problems and to create new usage of the spaces in order to respond to the changes of the family's lifestyle. The husband and other family members kept struggling to modify and maintain the details and space in order to adjust the environment to their needs and feelings, collaborating with Ikebe to make it their own.

As he attached importance to the flexibility of life space and production systems, his designs of houses were based on simple structures and on the flexible arrangement of plans. He gave serious consideration to the engineering systems in the kitchens and bathrooms, and tried to rationalize the housewives' working place as much as possible. As Nanba Kazuhiko, one of his pupils, stated in his book on Ikebe, Ikebe tried to force clients to inquire about the appropriateness of their habitual lifestyles in that logically designed space, and let them work on their houses by themselves [Nanba 1999]. Thus, in such dialectical communication with clients in the actual examination of the scale and engineering of the house, Ikebe examined the communication methods in the design process.

Fig. 7. House No. 71. Third stage, second-floor plan (Owner's private collection)

Fig. 8. House No. 71. Third stage, first-floor plans (Owner's private collection)

Fig. 9. House No. 71. Third stage Elevation (Owner's private collection)

System theories and the idea of module as a flexible mathematics for creation

In the last stage of his career, Ikebe presented various ideas of design system theory, which were later developed in the ideas of space syntax by his pupils. Two of them, the modular coordination on an urban scale, and Design Sugoroku (Parcheesi), are essential for understanding their relationship with his idea of module:

- The modular coordination on an urban scale: In his article “Ningen-shugo-wokisoni” (Considering architecture based on the nature of human gathering) [Ikebe 1979], Ikebe stated that we have to conceive housing space as interrelated to its outside space, and created a diagram showing an order in the scale transitions from individual space to the whole environment. He argued that by conceiving the idea of dwelling from the nature of human gathering, we would be able to design architecture from a wider social viewpoint (fig.10).
- Design Sugoroku (Parcheesi): Ikebe conceived this diagram as the correlative network of the factors in design. He specified ten elements; Work, Cost, Tradition, Purpose, Appearance, Material, Distribution, Environment, Function, and Standard, and grouped them into three categories: those which relate to the users, producers, and social conditions. Through examining any one of these elements, the idea would develop into a substantial design. By passing through the centered element of Standard, the development of ideas and the collection of information will be systematically organized to facilitate teamwork in architectural design (fig.11).

Fig. 10. Ikebe Kiyoshi's conceptual diagram: The modular coordination in urban scale [Ikebe 1979]

Fig. 11. Ikebe Kiyoshi's Design Sugoroku [Ikebe 1979]

These diagrams represent Ikebe's intentions to extend the ideas of the module and standard into a general system to make all information accessible to all participants. He thought that the psychological and social factors of architecture could be studied more clearly and qualitatively by organizing the relationships between human and environmental factors in geometric diagrams. In other words, these design system theories are synthetic systems of communications based on geometrical orders. In these theories, Ikebe cultivated four approaches:

1. putting a lot of emphasis on feedback from practice into theoretical studies;
2. creating new flexible logical structures for the design process;
3. trying to develop a method to incorporate the ambiguous factors of human life; sensual and habitual, into the idea of architectural performance;
4. reinterpreting the idea of module and standard as the communal base for collaborators to answer the economical, technological and social demands.

Conclusions

As explained above, Ikebe Kiyoshi was consciously opposed to Le Corbusier, and presented his idea of module from his different viewpoint and interpretation of mathematics and architecture. He focused on its social, cultural and physiological meanings, attempting to return to the primal inquiry about man's relationship with his environment. For him, mathematics is not an abstract form or number but something both substantial and metaphorical, capable of organizing human thinking and creation, and which should clarify the cultural significance of Japanese people's living space beyond the ideology of Westernization. Ikebe's attempts to reinvent an idea of the module was also the rediscovery of the role of the architect in taking and inventing a balance between multiple and flexible human and social factors in architectural production.⁹

In 1958 renowned Japanese architect Isozaki Arata criticized Ikebe's ideas, saying that the conflict between architects and clients cannot produce a standardized solution for housing, and the mainstream of housing production would be dominated by identical housing determined by the bureaucracy and with readymade houses by the housing industry. Isozaki also envisioned that outside of these domains architects would only design irrational houses.¹⁰ Actually, in the history of Japanese modern architecture, Ikebe's designs have been mostly appreciated for their rational and logical approaches without considering his critical consciousness of modernizing society and his presentations of alternative ideas for the relationship between mathematics, beauty, technology and architecture.

Since Ikebe's death in 1979, the prefabricated housing market has expanded dramatically to answer the need all over Japan for high technological performance, and comfortable living environment.¹¹ The developments of visual technologies are transforming the relationship between our perceptions, forms, architectural space and production [Nanba 2007]. Such phenomena raise serious questions about the humanistic foundation of architectural creation, and the social and cultural meaning of our living environment, and the necessity to reexamine the meaning of the unification of human scale, forms and productions of architecture. Through examining the process used by Ikebe to create the module, and the prefabricated and standardized minimum house, we can see

that Ikebe's ideas were not only embedded in his social and cultural consciousness against the modernization of Japanese architecture, but also presented alternative tactile, substantial and flexible approaches for its realization. This analysis of Ikebe's ideas and works argues that, even though Ikebe shared the modernist ideology and dreams in mathematical rationality and industrial technologies with Le Corbusier, he conceived different frameworks of their relationship with people, and, beyond Isozaki's cynicism, explored further possibilities to respond to the problems of architectural production of our time.

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Notes

1. For example, among the developing countries in Asia, the deliberation of public housing for economically underprivileged people is a most urgent social issue. The greatest difficulties related to the discussions of housing concern their close relationship with the social, economic, cultural and technological problems, and with these multidisciplinary problems, the ideas of standardization and module for architectural production have been discussed as one of the key issues.
2. There are two other scales, Sun and Ken for this module.
3. Kiwari deals with the basic arrangement of columns and beams according both to the functional needs of buildings and to the structural balance and strength of members.
4. Hashirawari determines the styles of buildings, their interior arrangements, ornament and other architectural fixtures.
5. The committee decided on this definition of module, "Module is the basic element of architectural measurement, which gives a certain order in the usage of the measurement in the entire area of architectural production; the production of architectural materials and parts, as well as the whole aspect of design and construction, and it enables the mass production of architecture."
6. Jean Prouvé started his career as a blacksmith and craftsman, but extended his creative involvement to the design of prefabricated buildings. In 1930 he was involved in the group UAM, which was dedicated to establishing a connection between art and industrial production, with Le Corbusier, Charlotte Perriand, Pierre Jeanneret and others.
7. In his doctoral thesis on the idea of module [1961], Ikebe explained that European modernist architects conceived their ideas of module inspired by Japan's traditional *shaku* systems, but that Japanese people had been so used to its advantages that they are now learning from those European ideas and having difficulties in creating a new module. See [Nanba 2007].
8. This house is author's parents' house, and this section is based on my actual experience in eighteen years as a resident.
9. Ikebe briefly explained how he was challenged to resolve contradictory problems in defining a module system as a condition for flexible designing. See [Ikebe 1955].
10. Furthermore, one of the limitations of Ikebe's houses was that they often cost more than other public housing and readymade houses.
11. Prefabricated houses now dominate Japanese urban and rural landscapes, ignoring their local cultural identity. They have also changed from an inexpensive to an expensive, tailor-made commodity.

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